

THURSDAY, FEBRUARY 15, 1883

## THE TERTIARY HISTORY OF THE GRAND CAÑON DISTRICT

*A Monograph by Capt. C. E. Dutton.* Being Vol. II. of the Monographs of the United States Geological Survey. With Atlas. 4to. [Vol. I. is not yet published.] (Washington, 1882.)

IN a handsome quarto volume, with a large atlas of maps and coloured views, the recently-constituted United States Geological Survey begins its series of memoirs descriptive of the geological structure and history of the country. Most appropriately the subject selected for illustration is at once the grandest and most unique feature in the geology of the United States, and to which indeed there is no parallel elsewhere in the world. Ever since the early Report by Ives and Newberry, in which the marvels of the Rio Colorado of the West were first made known, there has been a strong desire among geologists to learn more of that region, to have accurate measurements and careful drawings, and to be told authoritatively the details and the history of what they could not but admit to be the most stupendous example of river-erosion on the face of the globe.

Major Powell's bold descent of the river and the charming volume in which he described it threw much fresh light on the wonders of the cañons. But he had no opportunity of properly exploring the surrounding regions, though we looked forward to his return to the scene of his exploits and the consequent elaboration of another memoir discussing the whole problem of the origin and history of the geological features of that remarkable area. Pressure of other duties has prevented him from realising this hope. But, though unable himself to resume this task, he deserves our best thanks for having induced the late Director of the Survey, Mr. Clarence King, to intrust the detailed survey of the Grand Cañon to Capt. C. E. Dutton, who had already done excellent service among the high volcanic plateaux farther north. Capt. Dutton unites some of the highest qualities of a geological explorer. He is an excellent stratigrapher, a good petrographer, an enthusiast in the study of rock-sculpture, writes clearly and pleasantly, has a physical frame capable of carrying him triumphantly through any amount of physical fatigue, and is the happy possessor of a bright, cheerful nature, that must lighten the hardships of camp-life in the remote West both for himself and for his companions. We can well imagine how such a man, wandering among the lofty plateaux of Utah that had been assigned to him for exploration, should have cast many a longing gaze southward to that strange wild desert region of rocky platforms and winding *mesas*, through which the gorges of the Colorado and its tributaries have been sunk; how he should have been unable to resist the temptation to stray into that wonderland; and how he must in some measure have almost welcomed the blasts of early winter that drove him down from the survey of the plateaux, and allowed him to journey through the cañon country on his way back to the Mormon settlements and the nearest railroad.

When at last the task of actually exploring and describ-

ing that region was intrusted to him, he already possessed a general acquaintance with its character and with many of its details. A stranger who first finds the cañon scenery before him is so excited by its novelty and grandeur, that for a time he feels utterly bewildered. Only after his eye has in some measure recovered its power of grasping the broad effects, without being lost in the details, does he begin to realise what are the elements of this stupendous grandeur. But Capt. Dutton had gone through this preliminary training. He had been led to scrutinise the scenery in detail, to discover the relations of part to part, and to speculate upon the evolution of the whole. Yet no one can read his pages without feeling that this analytic process has in no way dulled his sense of the beauty and majesty of the scenery. His words glow with the light that floods those flaming precipices. The blue aerial perspective of chasm and cliff receding into the dim distance in the central gorge seems to rise before our eyes as we read. With no irreverent hand does he tear the mask off the face of Nature. Rather does he make us feel how deeply the mystery of the scene has entered into his soul, as he gently lifts the veil that we may see a little way within, even as far as he has himself been enabled to penetrate.

And this is the true spirit in which such scenery should be described and discussed. The man who could sit down and dissect these cañons in cold blood, and with as little emotion as he would show in cutting up a joint of beef, would be a creature not to be envied. Nowhere in this world does the scenery appeal so powerfully to the imagination. Among the Alps the rocks have been so stupendously crumpled that we may be pardonably at a loss to tell how far the outlines of a mountain are due to subterranean movements or to subsequent erosion. But among the western cañons there is no room for any such doubt. The rocks lie for thousands of square miles as flat as when they were laid down upon the floors of ancient seas and lakes, and their horizontal undisturbed beds may be followed by the eye, winding in and out from cliff to cliff, preserving the same breadth, colour, features, and serving as so many datum-lines from which to measure the amount of solid rock that has been removed from the gorges. In tracing back the origin of these landscapes, and seeking out the causes of their infinite variety of detail yet marvellous harmony of effect, the mind naturally compares them with the feeble illustrations of erosion with which alone we are usually personally familiar. Such a comparison, however, will almost suggest a doubt as to whether we ever before could have had any proper conception of what the power of running water actually is, so utterly beyond description is the impressiveness with which this power is now realised. Nor is one disposed to deny that nowhere else is the dominant influence of geological structure upon the ultimate contours developed by erosion so significantly displayed. On every part of the scenery the story of its origin is impressed in characters that cannot be mistaken. Yet these characters are on so colossal a scale that the dry prosaic language of ordinary geological description seems utterly incongruous when applied to them. It must be a difficult task to preserve the sober decorum of scientific treatment, and to convey at the same time an adequate impression of the infinite majesty of the subject.

Capt. Dutton may be congratulated on having accomplished this task with as large a measure of success as probably was achievable. Without entering into stratigraphical details he addresses himself to the problem of the origin and history of the erosion that has converted the level rock-platforms of the Colorado River into their present profoundly trenched condition. Sketching briefly but clearly the general geographical features of the region and their relation to the underlying geological structure, he presents the reader with a series of pictures of the various types of scenery. He shows how everywhere the evidence arises of vast denudation. Not only have the wide valleys and deep gorges been excavated, but an enormous amount of material has been worn away from the broad rocky terraces. From the high plateaux of Utah the Mesozoic and Tertiary formations descend by a succession of broad terraces like a giant staircase to the platform of Palæozoic rocks. Capt. Dutton gives reasons for his belief that the strata which end at the cliffs of these successive terraces once extended over the whole of the Grand Cañon district, and he estimates the amount of rock thus removed to have averaged probably 10,000 feet in thickness over an area 13,000 to 15,000 square miles in extent. He bases this estimate partly upon the obvious continuity of the strata, and the improbability that they could have ended off upon the Carboniferous platform; partly upon the evidence of displacements whereby Palæozoic rocks, formerly buried at least 10,000 feet below the sea-level, under an accumulation of sediment of that depth, have been again uplifted into the lofty plateaux of the Colorado; partly upon an argument from the history of the drainage-lines of the district. In this last argument, developing the views so forcibly expressed by Jukes many years ago for the rivers of the south of Ireland, and more recently applied by Powell to the stupendous illustrations in the Colorado basin, he shows that the present courses of the rivers are so entirely independent of structural features, that their position is inexplicable save on the interpretation that when the streams began to flow these features had not revealed themselves. He thus smoothes over the faulted Carboniferous platform, piles over it a covering somewhere about two miles thick of Mesozoic and Tertiary strata, and makes the rivers begin their first erosion on the surface of this covering. The faulting, plication, and uplifting have taken place subsequently; but meanwhile the rivers have kept their courses, incessantly sawing their way downward into lower layers of rock, and across the dislocations and folds that subterranean disturbance might throw across their path. No thoughtful student of this subject can refuse his assent to the solution of the problem so well worked out.

In tracing the geological history of the cañon region, we find at the bottom of all the visible strata, a foundation of ancient crystalline Archæan rocks, and also crumpled and broken masses of stratified formations, referred with more or less confidence to the Silurian and Devonian periods. The disturbance and extensive denudation of the older Palæozoic masses had been effected before the lowest of the vast conformable series of formations in this region began to be deposited, for the latter lie upon the upturned edges of the former, as on a platform—an impressive feature in the scenery. Continuous

sedimentation began some time in the Carboniferous period, and appears to have been carried on with no sensible break up to the close of the Eocene period, until a total depth of at least 15,000 feet of sediment had accumulated. The Carboniferous portion is estimated at a thickness of 4500 feet, the various Mesozoic formations at 9000 or 10,000, and the portion of Eocene lacustrine beds deposited were 1000 or 1200 feet.

Capt. Dutton calls attention to the remarkable uniformity and persistency of the lithological characters of each formation, while at the same time there is great diversity in those respects between the strata of different platforms. By far the larger proportion of the whole mass of conformable strata consists of sandstone, presenting on successive horizons the most extreme contrasts of structure and colour, for they consist along certain platforms of adamantine quartzite, in others of massive cross-bedded sand-rocks, while they graduate also into shales and these into marls. It is this alteration of strata, showing very different degrees of permanence, yet each retaining its normal characters over vast areas, that affords the key to much that is most characteristic in the scenery of the region. The limestones are almost wholly confined to the Carboniferous system, where they occur both in the lower and upper divisions.

Another significant feature brought out by the survey is the evidence that sedimentation went on nearly at sea-level during the whole of Mesozoic time throughout the Cañon province. As the Mesozoic strata are 9000 or 10,000 feet thick, it is obvious that the sediments which were at or near the sea-level at the beginning had sunk to that distance below it by the end of the period. We have here, therefore, a consecutive series of shallow-water deposits not much less than two miles in vertical thickness. The Cretaceous rocks which form the uppermost division of this series are from base to summit banded with seams of lignite or coal, and layers containing marine mollusca. They vary in different parts of the province from 3500 to 8000 feet in thickness. At the close of their deposition, those movements appear to have begun which have culminated in the elevation of the sea-floor into the elevated plateaux that now form so prominent a feature on either side of the watershed of the continent.

With the advent of Eocene time the shallow sea-floor, in which sedimentation had been so continuous during the whole of the Mesozoic ages, began to be converted into wide fresh-water lakes. The Tertiary history of Western America is in large measure a record of the formation, duration, and effacement of these lakes, as the land gradually increased in elevation. In the plateau country the Eocene lacustrine deposits range from 1000 to 5000 feet in thickness. Great as this accumulation is, it unquestionably took place in comparatively shallow water over an area that was generally rising, yet was locally sinking, so that the lake persisted, and remained shallow; for its depth was reduced by the deposit of sediment as fast as it was increased by subsidence. The waters appear to have dried up from south to north, and finally disappeared somewhere in the area of the Uinta mountains.

It was on the floor of this desiccated lake that the drainage system of the Colorado river began, somewhere about the close of the Eocene period. During the vast

succession of ages that have since elapsed, erosion has been continuously in progress, and the result is the scenery of the Cañon region. Capt. Dutton gives what appear to be good reasons for believing that the larger rivers flow along the same channels which they took at the beginning, but that the minor tributaries, where any exist (and they are conspicuously absent in some wide districts), are comparatively recent in origin, and have been determined by modern surface conditions. The excavation of the Grand Cañon of the Colorado has thus been going on ever since the Eocene period. During that enormous interval the climate of the region appears to have passed through successive oscillations. There is no more skilful feature of the volume before us than the way in which the scattered facts that bear on this question are marshalled to their places and made to tell their story. Ancient river-beds, which for ages have been dry and are partly filled up with debris, open on the edge of the great chasm. They doubtless discharged their waters into the main river at a time when rains were abundant and watercourses numerous. But their fountains have long since been dried up, and their fading channels are almost gone. But all the while the Colorado and its larger feeders, drawing their supplies from far well-watered uplands, have continued their task of erosion until they have sunk their channels in some places more than a mile below the level of the plateau across which they flow.

The process of the excavation of the Grand Cañon is treated at length, and much new information is given as to its varying conditions. The details of the erosion are described with great clearness. The two final chapters, wherein these subjects are discussed, contain much that is suggestive, and deserve careful perusal by all who take interest in questions of denudation. They are condensed pieces of reasoning which cannot be intelligibly summarised here, and which indeed one is hardly prepared to find in an official report. Like his colleague, Mr. G. K. Gilbert, Capt. Dutton properly lays great stress upon the influence of an arid climate as one of the chief factors in cañon excavation. He points out how the absence of vegetation exposes the surface of bare rock to the action of rain. But it may be doubted if the scanty rains of the region can do more than remove material already disintegrated. We have to account for the continuous lowering of the level of the plateaux, and the removal of so vast a depth of stratified rock from their surface. Capt. Dutton himself admits that most of the rain which falls upon the country is absorbed by the rocks, and gushes out in copious springs at the base of the cañon-walls, thereby notably increasing the volume of the river. But there is everywhere a perceptible disintegration of the rock at the surface. This decay cannot be attributed to frost, which in so dry a climate can have but small effect. It seems to be due in large measure to the superficial strain induced by a great daily range of temperature. And it is no doubt aided by the action of wind, which removes the loosened particles, and exposes a new surface to the same kind of disintegration.

In conclusion, reference must be made to the truly magnificent series of illustrations by which this monograph is accompanied. The maps of the atlas give the reader a clear mental picture of the general topography and geological structure of the region. But it is by the

pictorial illustrations that he will be chiefly fascinated. These are scattered profusely through the text, and form an important feature in the atlas. Mr. Holmes, whose reputation for the accurate and artistic rendering of geological details is so well established, has here far surpassed all his previous efforts, and has produced the most impressive and instructive geological pictures that have ever been made. His large coloured views of the Grand Cañon are in themselves a series of lessons in geology far more interesting and effective than can be supplied in words. The United States may be heartily congratulated on this first of the monographs of their Geological Survey. Let us hope that Congress will continue in the same liberal spirit the annual appropriations that have enabled the Director of the Survey and his associates to produce such splendid results. ARCH. GEIKIE

#### CENTRAL ASIA

*Travels and Adventures East of the Caspian during the Years 1879-81, including Five Months' Residence among the Tekkés of Merv.* By Edmond O'Donovan. Two Vols. (London: Smith Elder, 1882.)

*Wanderings in Baluchistan.* By Major-General Sir C. M. MacGregor, K.C.B. (London: Allen and Co., 1882.)

MR. O'DONOVAN'S venturesome excursion to the Merv Oasis stands out conspicuously as perhaps the most romantic episode in the recent annals of Central Asiatic travel. Yet in proceeding eastwards his original goal was not the Mervli Turkomans, but their western kindred, the Akhal Tekkés of the Daman-i-Koh. Sent out as the Special Correspondent of the *Daily News* with the Russian expedition against those nomads in 1879, he was at first well received, and spent some profitable time during the progress of military operations on the Caspian seaboard. But after the death of General Lazareff, having been suddenly banished from Chikislar, his ramblings lay henceforth mainly within the North Persian frontier. Here he again went over the ground, with which we have been made tolerably familiar by V. Baker, Macgregor, Stewart, and other recent explorers. Nevertheless even of this region Mr. O'Donovan has much to tell us, which is both new and interesting. There is a freshness and a fulness of detail in his account of Meshed, Tehrán, Kuchan, Resht, Shahrúd, as well as of the people and scenery of Khorasán and Mazandarán, which lend a peculiar charm to the first of these brilliantly written volumes.

But the chief interest of the work naturally centres in the section devoted to the Merv Oasis and its Tekke Turkoman inhabitants, with whom the traveller passed a forced residence for over five months during the year 1881. How he eluded his Persian escort, crossed the border above Sarakhs, traversed the Tejend river valley, plunged boldly into the heart of the desert, safely reached the Murghab Oasis, allayed the suspicions of the Tekkés, who took him for a Russian spy, gradually gained their confidence, became in fact a "Tekke of the Tekkés" and head of a Turkoman triumvirate, finally, by a rare combination of tact, patience, and courage, again escaping from his too importunate friends, all reads far more like a wild piece of fiction than so much sober history.